Improvement in Heart Rate Variability Following Spinal Adjustment: A Case Study in Statistical Methodology for a Single Office Visit

John Hart*

Hart Chiropractic, Greenville, South Carolina, USA

Abstract: *Introduction*: Statistical analysis is typically applied at the group level. The present study analyzes data during a single office visit as a novel approach providing real-time feedback to the clinician and patient regarding efficacy of an intervention. In this study, heart rate variability (HRV) was analyzed *before* versus *after* a chiropractic spinal adjustment.

Methods: The patient is an adult female who signed a consent form for the study. HRV was measured twice before a chiropractic adjustment and once afterwards using app-based technology. The three HRV values (two pre and one post) were then statistically analyzed using an online calculator for outliers using Grubbs test.

Results: The two pre-adjustment HRV (rMSSD) readings were consistently low: pre 1 = 16.0 milliseconds [ms] and pre 2 = 16.2 ms. The low HRV was an indicator that the patient's nervous system was not functioning optimally. The patient's atlas (C1) vertebra was palpated to be slightly out of alignment. These two findings (low HRV and vertebral misalignment) indicated the presence of a chiropractic subluxation (of the atlas vertebra). The subluxation was adjusted and within minutes the HRV increased (improved) to 27.5 ms. This improvement was calculated to be a statistically significant outlier ($p < 0.05$).

Conclusion: This study is an example of how statistical methods can be applied to the level of an individual patient during one office visit to assess neurological effectiveness of a chiropractic adjustment. Since this is a case study, the results may not apply to all patients. Therefore, further studies in other patients, and for longer follow-up times, are reasonable next steps.

Keywords: Chiropractic adjustment, heart rate variability, biostatistics, Grubbs test.

INTRODUCTION

Research on effectiveness of an intervention using statistical analysis is typically done at the group level rather than at the level of the individual patient. Group studies are typically conducted over a period of weeks or months to determine efficacy of an intervention. In group studies, there may be some individual patients who do not respond to the intervention even though on average the group shows a benefit. Nonetheless, studies at the group level can provide important information that may be applied to the level of the individual patient.

In practice, many clinical interventions require a period of time such as days, weeks or months before it can be determined whether the intervention is effective. A previous case study by this author and colleague used statistical methods for an individual patient who received one chiropractic adjustment. That study spanned the course of approximately 1 month, comparing three pre-adjustment resting heart rate measurements to 21 post-adjustment measurements using the two-sample *t* test [1]. In the aforementioned study, [1] an immediate post-adjustment measurement in the same office visit was not obtained. Since then, the author has included immediate post-adjustment measurements and has observed beneficial changes within minutes after an adjustment.

Recently, the author tested a small group of his patients for a single visit, comparing pre-spinal adjustment heart rate variability (HRV) to post-spinal adjustment HRV [2]. The present study also compares pre-post HRV for one visit, *but for one patient*, where application of statistical analysis would seem to be more challenging with such a limited amount of data. Use of inferential statistical analysis in this way may be of interest to clinicians and patients to determine whether any changes that might occur during a given office visit are due to chance alone.

Clinical Significance of Heart Rate Variability

HRV is a gold standard, evidence-based method of assessing the health and adaptability of the autonomic nervous system [3]. Moreover, a healthy autonomic nervous system is a key component of a healthy life:

> *"The autonomic nervous system plays a major role in human homeostasis. Autonomic dysfunction and altered HRV*

*Address correspondence to this author at the Hart Chiropractic, Greenville, South Carolina, USA; E-mail: jhartdc@yahoo.com

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> *are observed in many life-threatening conditions, like myocardial infarction, multiple organ dysfunction syndrome, sepsis and severe brain injuries" [3].*

Generally speaking, a greater amount of HRV is considered neurologically healthier than a lesser amount of HRV [3-4].

Chiropractic Theory and Heart Rate Variability

HRV is a good fit for neurologically-focused practices such as those whose objective is to adjust *chiropractic subluxation*. A chiropractic (vertebral) subluxation is defined as a slight vertebral misalignment that disturbs nearby spinal nerve and/ or cord function, which in turn could disturb the autonomic nervous system. The ultimate goal in traditional type (subluxation-centered) chiropractic is to improve the health (e.g., the adaptability) of the nervous system. This in turn helps the patient to self-heal and maintain his or her health.

Purpose of the Study

The purpose of the present study is twofold: a) to show how statistical methods can be applied to an individual patient during a single office visit, and b) to assess neurological effectiveness of a chiropractic adjustment for this particular patient using HRV. In this way, caring for the individual patient during one office visit takes on a research component, generating real-time scientific evidence as to the effectiveness of a same-visit intervention. The benefit of this approach is that it shows immediate objective evidence to clinician and patient alike as to whether an intervention (such as spinal adjustment) was neurologically beneficial for the individual patient during a single office visit.

This case study appears to be the first of its kind, where a pre-intervention finding is statistically compared to a post-intervention finding for an individual patient in a single office visit using inferential statistics. This claim of novelty is made based on the author's search in PubMed on March 24, 2019 using keywords, *statistical analysis for a single office visit.* Only seven articles were returned, none of which pertained to an individual patient or a single visit.

CASE REPORT

The Patient

The patient is an adult female who occasionally experiences low back pain and consults the author periodically for wellness type care. The patient signed a consent form for the study and was asymptomatic for the office visit of this study.

Examination and Adjustment

The HRV measurement in the present study consisted of the time-domain measure of root mean square of successive differences in time between heart beats (rMSSD), measured in milliseconds (ms). A higher value for HRV (rMSSD) means greater neuro-adaptability and is therefore neurologically healthier than a lower HRV value [4]. As a side-note, this of course is the opposite of *resting heart rate*, where a *lower* number is neurologically healthier compared to a *higher* number. The terms *rMSSD* and *HRV* are used interchangeably in this paper.

Based on literature searches the author has conducted, normal average seated HRV (rMSSD) for healthy adults ranges from approximately 20 ms [5] to 30 ms [6] with the average of these two averages of course being 25 ms.

HRV was measured with smart phone app technology known as Heart Rate Variability Logger [7]. The app works with a Kyto sensor attached to the patient's earlobe that detects blood volume changes using the optical technology of photoplethysmography (PPG; Figure **1**). The sensor then sends a Bluetooth signal to the app. The set-up agrees well with ECG technology [8-9].

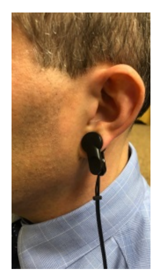


Figure 1: Kyto ear clip sensor [9] that works with the heart rate variability app.

The three HRV recordings (two pre-adjustment and one post-adjustment) lasted 1 minute each with a 20% R-R filter to remove artifacts [7]. In accordance with standard protocols, the measurements were obtained with the patient resting in the seated position after a minimum of 5 minutes seated rest.

The author theorized that if the HRV is worse (lower) than the minimum average (of 20 ms), then this would indicate less than optimal autonomic health. An autonomic disturbance (evidenced by low HRV), accompanied by a slight vertebral misalignment (determined by palpation in this study) would suggest the presence of chiropractic vertebral subluxation.

An atlas (C1) subluxation was diagnosed and the patient continued to be seated for the adjustment, given with a percussion type instrument (example in Figure **2**). The patient remained seated for the post-adjustment HRV reading (taken minutes after the adjustment). Consequently, three HRV measurements were obtained during an approximate 15-minute office visit. Chiropractic analysis and adjustment were performed by the author.

Figure 2: Example of the set-up for a seated atlas adjustment.

Statistical Analysis

Data were also analyzed by the author, using Grubbs test for outlier detection [10]. The test is based on the Z statistic and determines whether any single data point (HRV values in this case) has a statistically significant difference from the mean of all the data points. An outlier could be an unusually low or high value and could occur in the pre or post readings. An online calculator for the Grubbs test was used for the study, provided by statistical software developers at GraphPad (GraphPad Software, San Diego, CA) [11]. A two-tailed p-value less than the conventional significance level of 0.05 was considered statistically significant. A statistically significant p-value ($p < 0.05$) indicates the result probably did *not* happen by chance and is due to some other factor (such as a chiropractic adjustment).

A prerequisite for the Grubbs test is that the data exhibit a normal distribution. To check this for the small number of observations in this study, the three HRV measurements were assessed in a normal probability plot in Minitab 16 (Minitab, State College, PA). The GraphPad calculator requires a minimum of three values to obtain a statistical result so that requirement was satisfied.

RESULTS

The probability plot indicated acceptable normality, where the three data points were reasonably close to the plot's line and within the 95% confidence interval boundaries (Figure **3**). The acceptable normality is further substantiated by the plot's statistically *non*-significant p-value ($p = 0.065$, Figure **3**). Thus, Grubbs test was considered appropriate for these data.

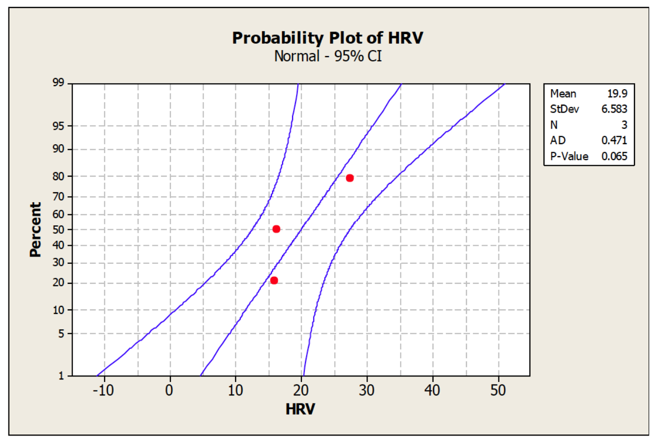


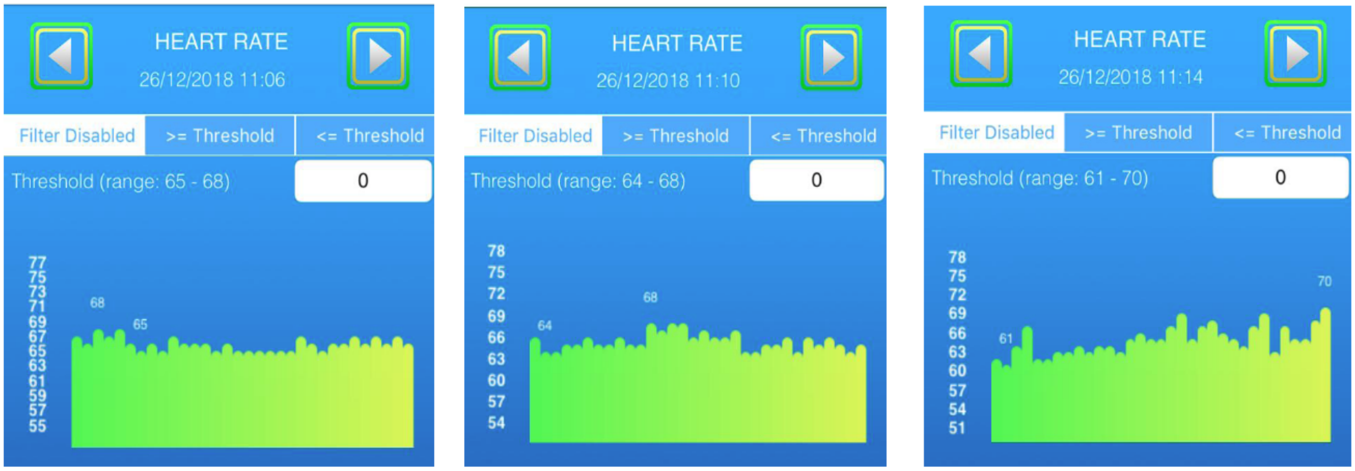
Figure 3: Normal probability plot showing acceptable normality for the three HRV measurements, within the 95% confidence interval (outer lines) and statistically significant p-value ($p = 0.065$).

App screen images for this patient are provided in Figures **4a-4c** and are as follows

- Pre-adjustment HRV reading #1 ("pre 1," Figure **4a**)
- Pre-adjustment HRV reading #2 ("pre 2"), obtained 4 minutes after pre 1 (Figure **4b**)
- Post-adjustment HRV reading ("post"), obtained 4 minutes after pre 2 (Figure **4c**)

In these screenshots, more bumpiness suggests higher HRV, verified by a higher HRV value.

The patient's two pre HRV readings were lower than the aforementioned average (of 25 ms) for normal healthy adults, where pre 1 was 16.0 ms and pre 2 was 16.2 ms (Figures **4a-4b**; and Figure **5**; Table **1**). The post-adjustment HRV reading increased (improved) to



a b c

Figure 4: a. Pre 1 (HRV = 16.0 ms). **b**. Pre 2 (HRV = 16.2 ms). **c**. Post (HRV = 27.5 ms).

27.5 ms (Figures **4c, 5**; Table **1**). This post-adjustment increase of 11.4 ms (27.5 ms-16.1 ms) was detected as an outlier that was statistically significant ($p < 0.05$, Figures **6**).

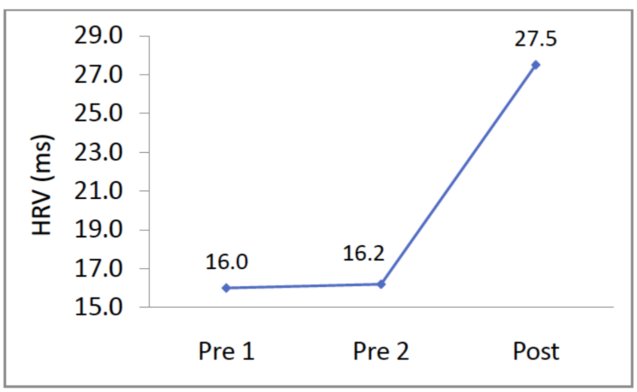
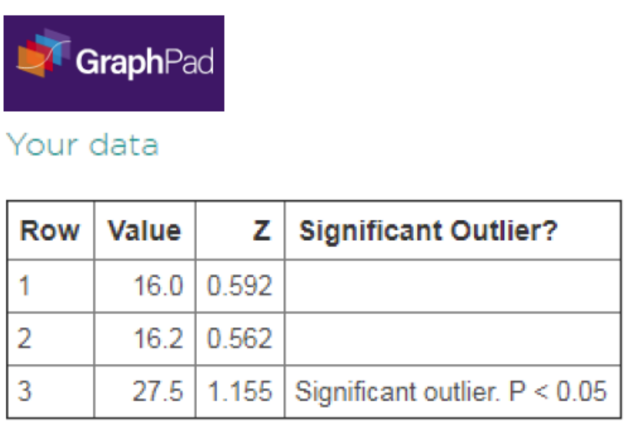


Figure 5: Graph of the HRV readings before (Pre 1 and Pre 2) and after (Post) spinal adjustment.



Row	Value	Z	Significant Outlier?
1	16.0	0.592	
2	16.2	0.562	
3	27.5	1.155	Significant outlier. P < 0.05

Figure 6: Screenshot of online outlier calculator [11] results for the two pre-adjustment (Rows 1 and 2) and post adjustment (Row 3) HRV readings.

DISCUSSION

The improved HRV following spinal adjustment in this case was detected as a statistically significant outlier, meaning the improvement probably did *not* happen by chance. Consequently, the chiropractic adjustment was most likely the reason for the improvement when no other intervention was performed. This is a strength of the study, that only one intervention was applied between pre and post adjustment. In other words, there were no other changes between pre and post measurements such as change in medication, caffeine intake, or life style changes that often have to be accounted for in longer term studies. Indeed, the patient did not change position during the study as she remained seated for all procedures (all HRV readings and the adjustment) during the 15-minute office visit.

Table 1: Summary Statistics for HRV Findings Before (Pre 1 and Pre 2) and After (Post) Spinal Adjustment

Reading	HRV (ms)
Pre 1	16.0
Pre 2	16.2
Post	27.5 *

*Statistically significant outlier ($p < 0.05$).

The improved HRV in the present study is consistent with previous chiropractic research on spinal adjustment and HRV [12-14]. The study is also consistent with chiropractic research that looked at other ANS-based measures such as hypertension [15-

16], resting heart rate [17-18], and pulse pressure [19]. The present study adds the dimension of statistical for an individual patient during a single office visit.

LIMITATIONS

Limitations to the study include: a) those that typically apply to an observational study such as this, e.g., findings may not apply to all patients; b) the length of time that the HRV improvement lasted beyond the single visit is unknown; c) the low number of data points (only three measurements, two pre and one post). Obviously, it would be statistically more robust to have more measurements. However, the point of the study was to show how statistical analysis could be feasibly applied to a limited amount of data - that is typically generated in a single office visit; and d) there may be a question about the clinical importance of an approximate 11.4 ms increase in HRV that was observed in this study. To address this latter concern, a previous study is considered - on diabetes and HRV at the group level. Here, patients with type 2 diabetes showed an approximate 1 ms lower (worse) HRV (rMSSD) compared to healthy controls [20]. Consequently, the 11.4 ms HRV increase following the adjustment in the present study for this patient appears to be a clinically important improvement.

CONCLUSION

This study shows how statistical methods can be applied to an individual patient for assessing autonomic change during a single office visit following a chiropractic adjustment. Such an approach allows the chiropractor and patient to know with reasonable certainty: a) whether a neurological benefit was achieved in a single office visit, and b) whether the benefit was due to the chiropractic adjustment. In this case there *was* such certainty, evidenced by the statistically significant improvement in heart rate variability following the chiropractic adjustment. Since this is a case study, the results of this study may not apply to all patients. Therefore, further studies in other patients, and for longer follow-up times, are reasonable next steps.

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